RIA and Stockpile Stewardship: The LLNL Perspective

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RIA and LLNL

Scientific Challenge: Determine the neutron flux in regions of enormous instantaneous neutron intensities (interior of stars, nuclear weapon tests, and NIF experiments) from remnant long lived nuclei.

- **Accurate neutron cross sections on short lived isotopes essential for accurate flux determination**
- **Most of the neutron cross sections on the relevant short-lived states have never been measured due to production limitations. RIA changes all that.**
- **Improved physical understanding of unstable nuclei allows more accurate calculations of cross sections where measurements are not possible.**

Enabling stockpile relevant measurements have been focus of LLNL R&D investments. Three main facility related issues are:

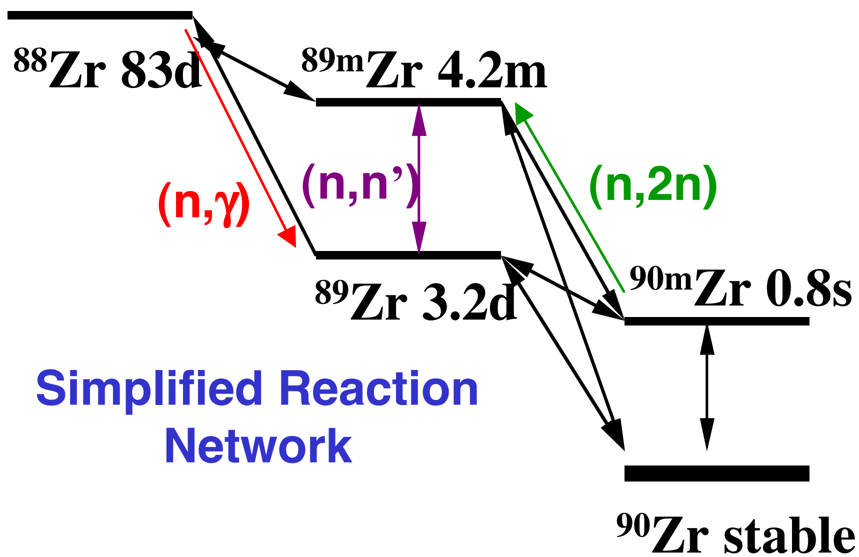
1. **Harvesting short-lived isotopes**
2. **Preparation of radioactive targets**
3. **Availability of an intense neutron beam**

Also important to astrophysics measurements

Addressing these challenges has led LLNL to investigate more general RIA R&D issues.

Nucleosynthesis, Radiochemistry, and Stewardship

Certain elements used as neutron flux monitors in nuclear weapon tests.



Simplified Reaction Network

Example – Load ^{90}Zr

1. Neutron flux causes nuclear reactions (nucleosynthesis).
2. Measure ratios such as ^{88}Zr/^{89}Zr (radiochemistry).
3. Compare with calculated value from simulation (stewardship).

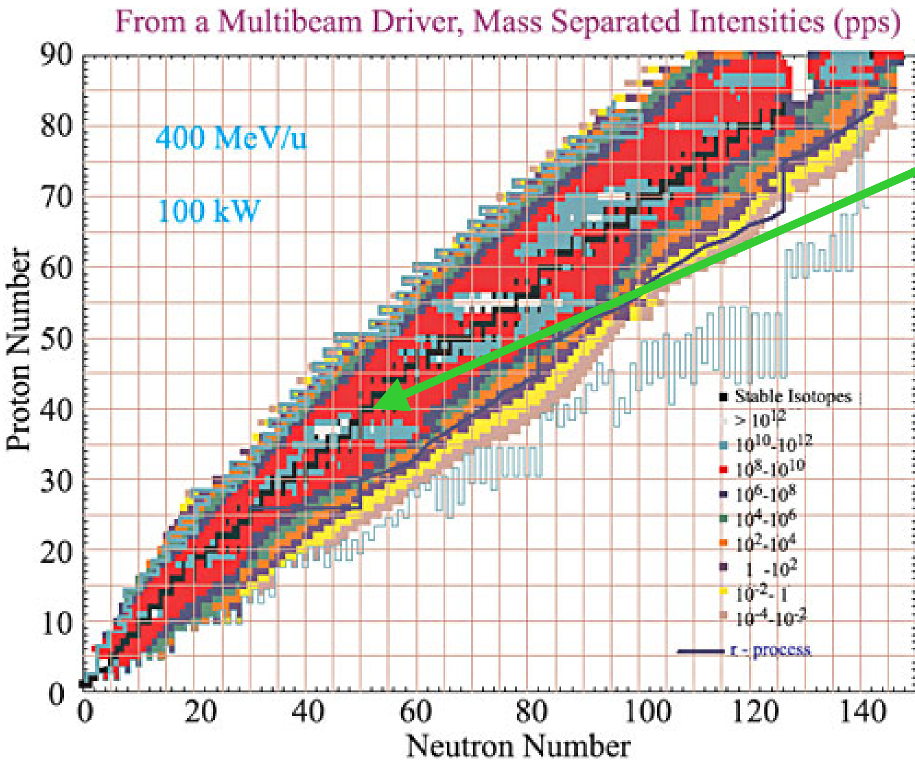
- Almost all isotopes in networks are unstable.
- Most reactions have no experimental data. (Zirconium network – 60 reactions, 5 examined experimentally).
- Similar diagnostics will be used at the National Ignition Facility.

Stockpile Stewardship requires more accurate knowledge of neutron cross-sections (0.1- 20 MeV) on unstable nuclei.

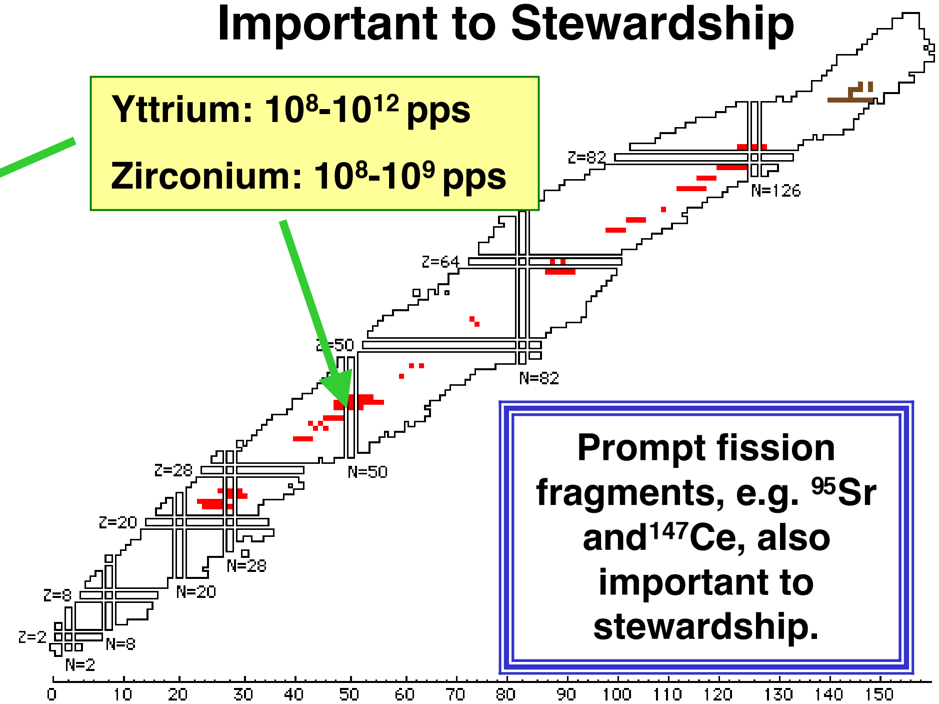
Why LLNL Values RIA

RIA enables improved cross-section evaluations for unstable nuclei important to stockpile stewardship.

Expected RIA Production Rates



Some of the Isotopes Important to Stewardship



- **LLNL also interested in astrophysics and nuclear structure experiments and theory.**
- **RIA will be training ground for future generations of nuclear physicists and radiochemists.**

LLNL's Role In Convincing DOE

LLNL has led the effort to generate NNSA support for RIA.

- **Beckner letter**
- **Classified briefing to Orbach by M. Kreisler.**
- **LLNL Attendees included:**
  - — **B. Goldstein, AD for P&AT**
  - — **E. Hartouni**
- **National RIA Steering Committee (Kreisler, Ormand)**
- **Presentations to Orbach**
- **Presentation to OMB**
- **Presentation to OSTP**

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

January 10, 2003

MEMORANDUM FOR: Dr. Ray Orbach
Director, Office of Science

FROM: Everet H. Beckner
Deputy Administrator for Defense Programs

SUBJECT: Rare Isotope Accelerator (RIA)

DISCUSSION: As discussed at our meeting on December 9, we believe that a future Rare Isotope Accelerator (RIA) will be important to science-based stockpile stewardship and therefore to the national security mission of the NNSA. There is significant interest at the NNSA laboratories in conducting experiments at an RIA to measure cross sections and reaction rates involving unstable, short-lived nuclei that would be extremely difficult to measure elsewhere. These data will provide the scientific underpinnings to reevaluate results from the radiochemical diagnostics used in the underground nuclear test program and to conduct precise determinations of neutron fluxes at new facilities such as the National Ignition Facility. Perhaps equally important, we also expect RIA to train many of the next generation of NNSA laboratory nuclear physicists.

While the NNSA could not build such a facility to fulfill the needs we have for nuclear data, we will be users with interest in nuclear science as well as in specific data. Scientists at the NNSA laboratories are already collaborating with scientists in the broader nuclear physics community to help design the best accelerator complex and experimental facility. If and when the Office of Science decides to proceed on the construction of RIA, the staff at the NNSA laboratories in general and at Livermore in particular are ready to help.

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Investing LLNL Resources

LLNL strategic interest involves investing its discretionary resources in the pre-project phases of RIA.

LLNL's scientific expertise and engineering resources would be valuable in solving many RIA R&D challenges.

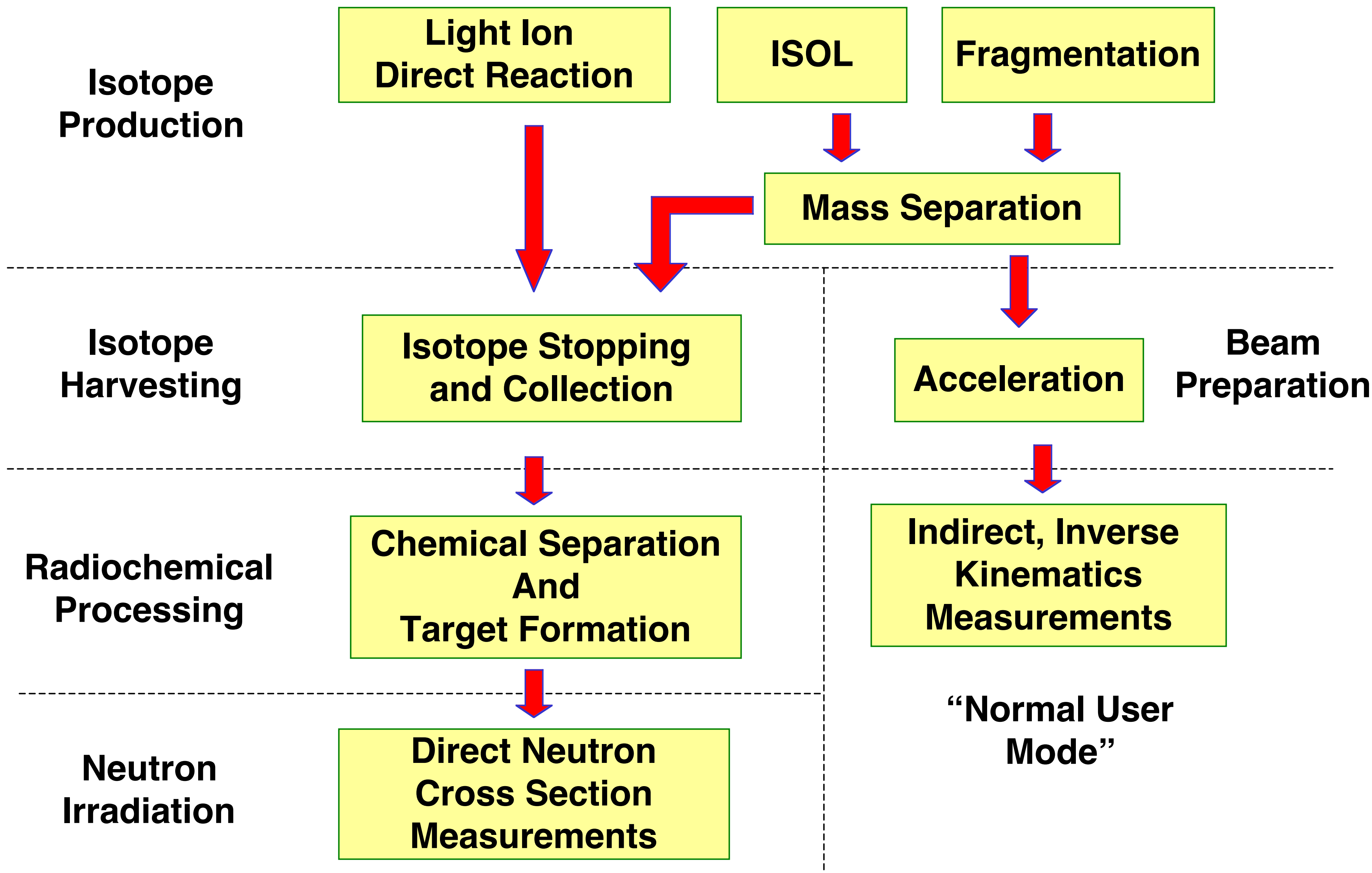
Areas of Expertise: Radiochemistry, mechanical engineering, neutronics, nuclear safety, RF engineering, systems integration…

LLNL Investment in RIA		
FY02 (Actual)	FY03 (Actual)	FY04 (Proposed)
0.3 FTE	1.2 FTE	4.0 FTE

Areas of investment:

1. Enabling stockpile stewardship measurements. (See talk by L. Ahle)
2. Fast RF tuning. (See talk by B. Rusnak)
3. Nuclear hazard classification. (See talk by J. Boles)
4. Beam dumps for fragment separator. (See talk by W. Stein)

Performing Neutron Cross Section Measurements at RIA



Indirect And Direct Measurements

Indirect Measurement

Use radioactive beams in inverse kinematics experiments to infer neutron cross-sections.

- **Improve nuclear data input for model calculation.**
- **Surrogate reactions, e.g. (d,p), to obtain information on (n,x).**

Required for isotopes with a half-life much less than one day.

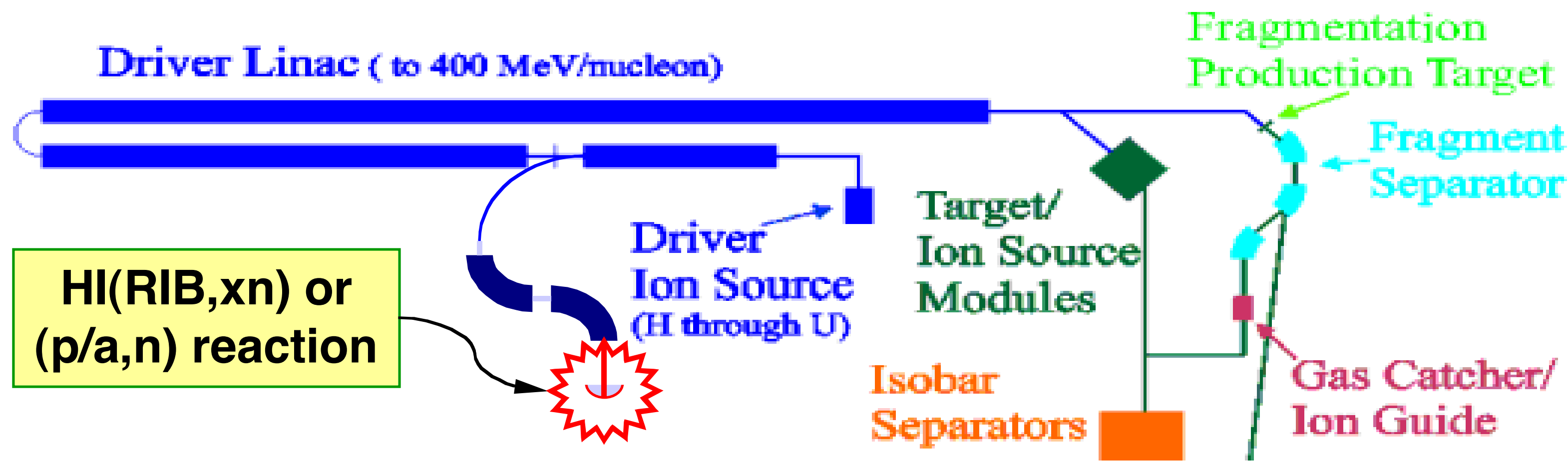
Direct Measurement

Collect desired isotope for target formation and irradiate with neutrons.

10 µg of a one day half-life isotope can be collected.

- **Delayed – irradiate then count produced products via spectroscopy.**
  - **Requires very pure target (1 in 10^9).**
- **Prompt – measure each reaction as it occurs.**
  - **Detector must handle high background rate from target.**

Possibility of Harvesting Isotopes at First Stripper



- Use (p/d,etc..,X) reactions or (HI,X) reactions on low Z targets to produce nuclei.
  - 100's of microamps of beam current
  - 50+ MeV protons and about 10's MeV/A ions
- No possible mass separation for p,d, etc… beams on heavy targets. Some possibilities for heavy ion beams.
- Probably only used in primary user mode (maximize production rates).
- Medical isotope community interested in this production method.
- Method works best for near stability, proton rich, low Z nuclei.

Harvesting: ISOL Versus Fragmentation

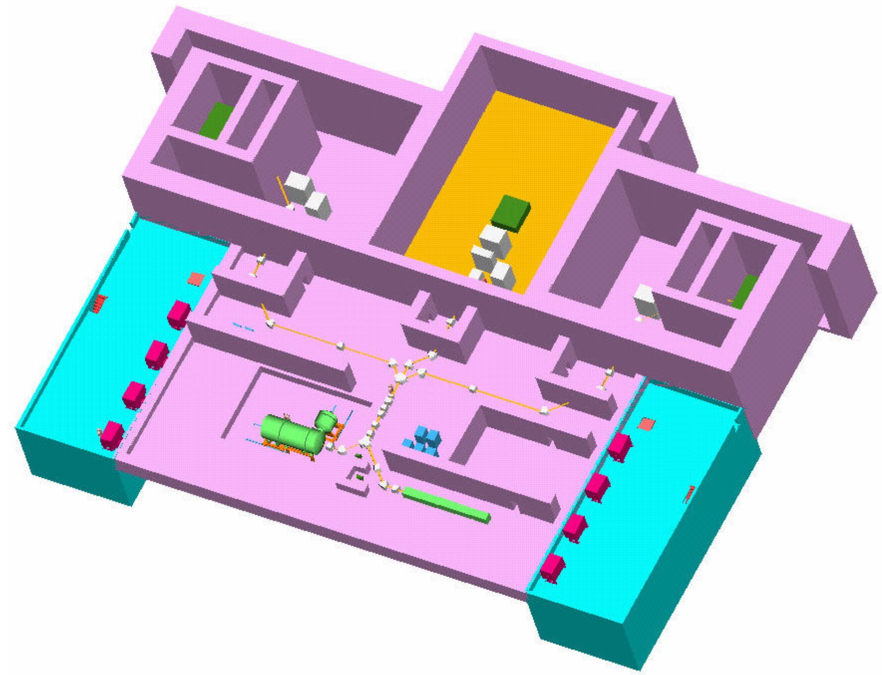
	ISOL	Fragmentation
Production Rate	As high as 10^{12}	~10^{11} at target: Limited to 10^{9} by IGISOL
Variety	Very chemistry dependent	Very Flexible
Mass Separation	Done on 60 keV ion beams	Done on ~350 MeV/A ion beams
Ion Collection	Stopping does not produce reactions	Stopping produces nuclear reactions, affecting purity
Impact as Primary User	Other ISOL target and low energy post acceleration line available	Choice of driver beam limited and only in-flight line available

Harvesting runs expected to be short (1 week), impact of stewardship measurements on rest of RIA scientific program will depend on …

- The number of ISOL target stations.
- How the primary beam is handled in the fragmentation separator.

Neutron Source Facility

- 3 MeV Dynamitron for white source of low energy (<200 keV) neutrons via $^{7}Li(p,n)$ or $t(p,n)$.
- 40 MeV variable energy linac for “monoenergetic” source of high energy (3 – 20 MeV) neutrons via d(d,n), d(t,n) or deuteron breakup.
- Radiochemistry facilities for target formation and chemical separation after neutron irradiation.



Issues for RIA Community

- Needs to be on RIA Site
- Transportation method for collected isotopes?
  - Underground rabbit system
  - Above ground

Accelerator Specifications

Accelerator	Maximum Energy	Beam Current (CW)	Species
Dynamitron	3 MeV	30 mA	p
Linac	40 MeV	1 mA	d

Number of ISOL Targets and Stewardship Impact

Factors that affect choice of number of ISOL target stations

- Maximum beam power on target.
- Need for target development.
- Target change out time.
- Cost

If 100 kW of beam power is maximum on a target:

- Driver linac can deliver enough beam power for 4 stations.

1. <15 MeV/A – Nuclear structure
2. <1 MeV/A – Astrophysics

Requires post-accelerators to be decoupled.

3. No acceleration – Traps, Laser Spectroscopy
4. Harvesting/Target Development

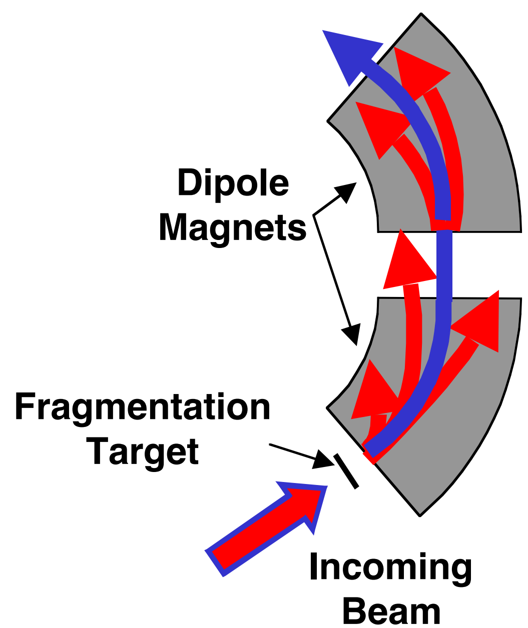
If 200 kW is maximum beam power on a target:

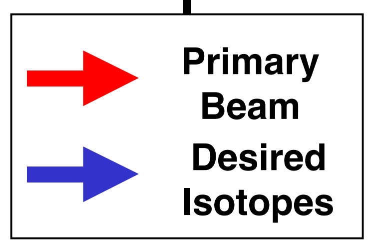
- Third ISOL station for harvesting/target development is still desirable. (Discussion at RIA Experimental Equipment Workshop – ORNL)

Extra ISOL target stations will lessen impact of stewardship measurements but it will increase complexity of target area.

Handling the Primary Beam in the Fragmentation Line

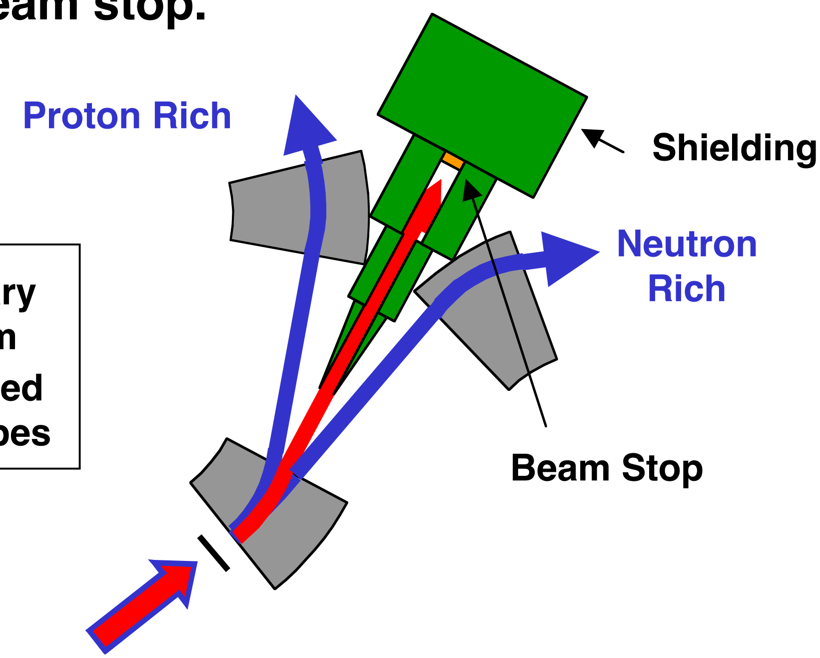
1. Primary beam can go anywhere.





- Beam stop is challenging
- Shielding against neutrons almost impossible
- Most flexibility in choice of isotope

2. Always "direct" primary beam to beam stop.



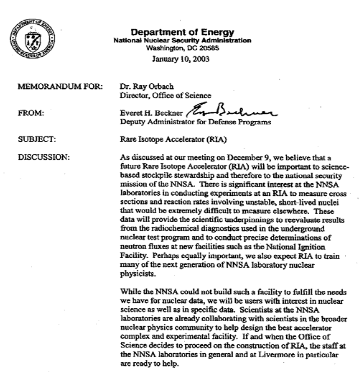
- Beam stop is easier
- Shielding against neutrons possible
- Possibly some loss in flexibility
- Possibly two users per target

Design study involving, beam optics, radiation hard engineering, thermal analysis, neutronics issues, mechanical design and nuclear safety is needed.

LLNL's Perspective

RIA enables improved cross-section evaluations on short-lived isotopes important to stockpile stewardship.

- **LLNL has worked hard to generate support in NNSA.**
- **LLNL recognizes its need to invest in the pre-project phases of RIA.**
- **Enabling many stewardship measurements and some astrophysics measurements requires:**
  - **Isotope harvesting capability**
  - **Radiochemistry facilities to form targets**
  - **A neutron source for target irradiations**
- **Design choices in ISOL target area and fragmentation line will affect impact of stewardship measurements on rest of RIA program.**



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